PE - 17

ANALYZING PHYSICS ITEMS OF UN, TIMSS, AND PISA BASED ON HIGHER-ORDER THINKING AND SCIENTIFIC LITERACY

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Abstract

This study aims to analyzing physics items of The National Examination (Ujian Nasional/UN), Trends in Mathematics and Science Study (TIMSS), and Program for International Student Assessment (PISA) based on higher-order thinking and scientific literacy. The higher-order thinking and scientific literacy has criteria: a) on the thinking process taxonomy of analyzing, evaluating, and creating, and also they are in the knowledge dimension of conceptual, procedural and metacognitive; b) having a divergent construct of item; not only to measure the competency in cognitive, but also to measure science process skills and affective; to facilitate several science process skills; the stem of item use the stimulus in the students daily life or the phenomenon near the students; and not only to measure the science cognitive but also to measure the student affective and how to use the science knowledge in their daily life. Sample of researched-items were 17 items of UN SMP/MTs 2013, 24 items of TIMSS 2007 (released items), and 17 items of PISA 2006 (released items). Results of this study showed: 1) the percentage of higher-order thinking and scientific literacy in physics items of TIMSS, PISA, and UN were 0.58; 0.53; and 0.35 respectively. The physics items of TIMSS, PISA, and UN also revealed that they are already related to the student daily life, but the items of PISA are higher in the aspect of contextual, complexity, and reality in the daily life than the others.

Key words: analyzing physics items, higher-order thinking, scientific literacy

INTRODUCTION

Zohar & Dori (2003) stated that directs the development of higher-order thinking skills of students is an important goal in education today. Higher-order thinking involves the ability to think logically, critically, creatively and demonstrate problem-solving skills.

Higher-order thinking skills not only in the academic context in the classroom, but also must be implemented in daily life called scientific literacy. Scientific literacy is different from science knowledge. OECD (2006) describes scientific literacy as a competency of students, so they can identify scientific issues, explain phenomena scientifically, and use scientific evidence to make decisions and communicate. Students that has high science knowledge does not guarantee has high scientific literacy too, but students that has good scientific literacy will always use their science knowledge in daily life, include solving some problems in daily life .

To know whether Indonesia's learning has been directing to the formation of higher-order thinking skills and scientific literacy, we can explore it by analyzing the assessment instruments that used. An example of assessment instruments which applied in national scale is the National Examination (UN). UN items are interesting to be analyzed because it is the final examination

of each level at education that takes a lot of efforts, money, and attention. Beside that, UN also becomes one of school quality benchmarks nationally.

Beside UN, the Ministry of Education and Culture (Kemendikbud) also send some representation of SMP/MTs and SMA/MA/SMK students of Indonesia in the international study, called TIMSS and PISA. The concern fact is Indonesian students always got low rank at TIMSS and PISA studies. While if reviewed from the UN results, graduation of Indonesian students almost 100% with its national value average each year is quite high.

Based on the description above, will appear an interesting question. Why the achievements of Indonesian students's abilities in the UN are quite high, but in the international study of TIMSS and PISA are always low? This study aims to analyzing the items of UN, TIMSS and PISA, especially the physics items of UN SMP/MTs 2013, TIMSS 2007 and PISA 2006.

The analysis results are expected to provide a comparative overview of physics items quality at UN compared to physics items quality at TIMSS and PISA, particularly related to higher-order thinking skills and scientific literacy. The comparison results are expected to be considered by teachers and Center of Educational Assessment when developing items.

RESEARCH METHOD

This research is a descriptive-exploratory research that explores information and analyze it deeply, then describes the information found comprehensively related to the level of higher-order thinking and science literacy in the Physics items of UN, TIMSS and PISA. The steps of research and the results obtained are shown in the table below.

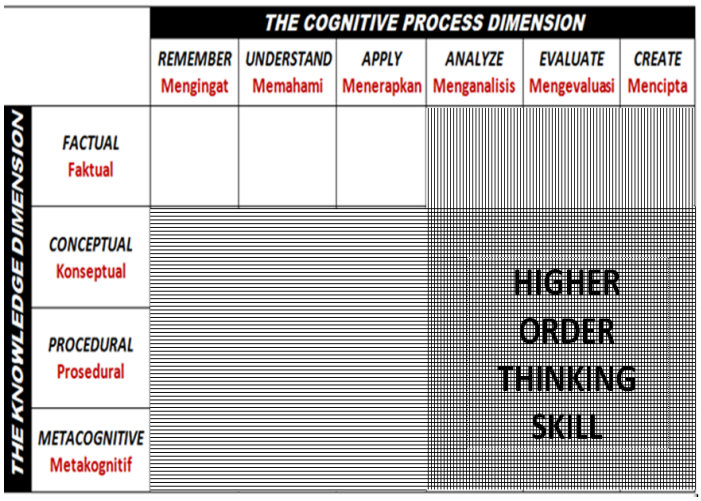
Table 1
The steps and the results of research

Activity	Results/Products
Search of materials and references	• Items of UN, TIMSS, and PISA • Comprehensive review about the level of thinking according to Bloom and scientific literacy along with its indicator
Identification of the aspect of higher-order thinking level and scientific literacy	Identification results of higher-order thinking level and scientific literacy in the items of : • UN • TIMSS • PISA
Comparison and validation of identification results	• Comparison of the identification results of higher-order thinking level and scientific literacy in the items of: UN, TIMSS and PISA. The comparison results are presented in the form of diagram/graph • The identification results of higher-order thinking level and scientific literacy in the items of: UN, TIMSS, and PISA has been validated by expert

RESULT AND DISCUSSION

The results of assessment instruments characterization of higher-order thinking skills and scientific literacy shows:

a. Higher-order thinking skills are on the thinking process taxonomy of analyzing (C4), evaluating (C5), and creating (C6), also in the knowledge dimension of conceptual, procedural and metacognitive. If described in the revised Bloom's taxonomy, it shown on the diagram below.



b. Item construction/assessment instruments of higher-order thinking skills and scientific literacy has characteristics :
   - Divergent, allow the appearance of several alternative responses or answers;
   - Not only measure the competence of knowledge, but also skill of process and attitude;
   - Train various skill of science process, such as: read/create a table, read/create a graph, perform inference etc;
   - Stem the item using stimulus in the form of real-life context or phenomenon that close to the students life;
   - Not only measure the science knowledge, but also measure the attitude and how to use that knowledge in daily life; and
   - The items not only have multiple choice form.

Comparison of the UN, TIMSS and PISA items based on aspect of higher-order thinking and scientific literacy are shown in the tables 2, 3, and 4.

Table 2
Characteristics of TIMSS Items 2007

No	The Cognitive Process	The Knowledge Dimension					%
		F	C	P	M	Total	
1	*Knowing*	2	2	-	-	4	0,17
2	*Applying*	(2;0)	(4;8)	-	-	14	(0,25;0,33)
3	*Reasoning*	-	6	-	-	6	0,25

Table 3
Characteristics of PISA Items 2006

No	The Cognitive Process	The Knowledge Dimension					%
		F	C	P	M	Total	
1	Remembering	-	-	-	-	-	-
2	Understanding	-	6	-	-	6	0,35
3	Applying	1	1	-	-	2	0,12
4	Analysing	-	6	-	-	6	0,35
5	Evaluating	-	3	-	-	3	0,18
6	Creating	-	-	-	-	-	

Tabel 4
Characteristics of UN Items 2013

No	The Cognitive Process	The Knowledge Dimension					%
		F	C	P	M	Total	
1	Remembering	-	1	-	-	1	0,06
2	Understanding	1	2	-	-	3	0,18
3	Applying	-	7	-	-	7	0,41
4	Analysing	1	5	-	-	6	0,35
5	Evaluating	-	-	-	-	-	-
6	Creating	-	-	-	-	-	-

Based on data in the three tables above, seen the percentage of demands of higher-order thinking process and scientific literacy in TIMSS items are 58% (C4: 0.33 + C5: 0.25), PISA items are 53% (C4: 0.35 + C5: 0,18), and UN items are 35% (C4: 0.35). Seen that the demands of higher-order thinking skills in items of TIMSS and PISA are higher than UN items. This is the possibility that cause the students achievement on TIMSS and PISA are lower than the students achievement on UN.

According to Ramos, et al (2013) higher-order thinking skills have a high correlation with academic performance, include: the ability to perform analysis, comparison, inference, and evaluation. While the study of Ramirez & Gannadea (2008) showed that creative activities give a significant impact on higher-order thinking skills. Beside built through the learning, the academic performance above also must be trained through the assessment instruments.

Arends (2001) stated that higher-order thinking has properties: not algorithmic, the action can not be fully specified previously; complex, so it can not be seen from one perspective only; multi-solution, not just has a solution, but has many alternatives with each advantages and disadvantages; requires consideration and interpretation; involves many criterias that sometimes contradictory one each others; often uncertain; demands self-regulation in the process of thinking; creates a new higher meaning; and illustrates the hard work and mental processes that occur earnest. It should be analyzed whether the items used in the UN, TIMSS and PISA encourage the growth of higher-order thinking skills.

The following are presented the samples of PISA, TIMSS, and UN items for the material of temperature and heat.

Sample item of PISA 2006

GREENHOUSE

Read the texts and answer the questions that follow.

THE GREENHOUSE EFFECT: FACT OR FICTION?

Living things need energy to survive. The energy that sustains life on the Earth comes from the Sun, which radiates energy into space because it is so hot. A tiny proportion of this energy reaches the Earth.

The Earth's atmosphere acts like a protective blanket over the surface of our planet, preventing the variations in temperature that would exist in an airless world.

Most of the radiated energy coming from the Sun passes through the Earth's atmosphere. The Earth absorbs some of this energy, and some is reflected back from the Earth's surface. Part of this reflected energy is absorbed by the atmosphere.

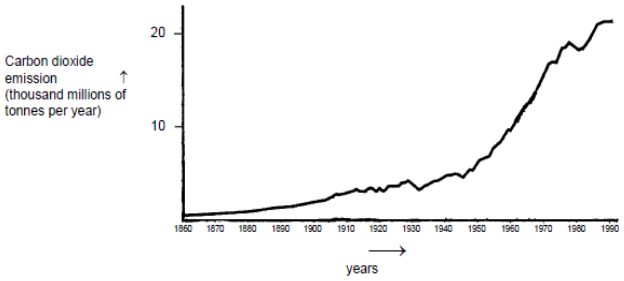
As a result of this the average temperature above the Earth's surface is higher than it would be if there were no atmosphere. The Earth's atmosphere has the same effect as a greenhouse, hence the term *greenhouse effect*.

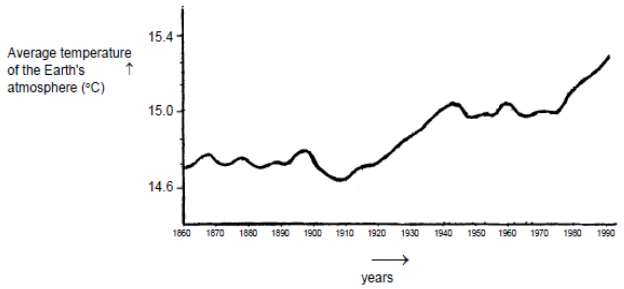
The greenhouse effect is said to have become more pronounced during the twentieth century.

It is a fact that the average temperature of the Earth's atmosphere has increased. In newspapers and periodicals the increased carbon dioxide emission is often stated as the main source of the temperature rise in the twentieth century.

A student named André becomes interested in the possible relationship between the average temperature of the Earth's atmosphere and the carbon dioxide emission on the Earth.

In a library he comes across the following two graphs.





André concludes from these two graphs that it is certain that the increase in the average temperature of the Earth's atmosphere is due to the increase in the carbon dioxide emission.

What is it about the graphs that supports André's conclusion?

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Another student, Jeanne, disagrees with André's conclusion. She compares the two graphs and says that some parts of the graphs do not support his conclusion.

Give an example of a part of the graphs that does not support André's conclusion. Explain your answer.

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André persists in his conclusion that the average temperature rise of the Earth's atmosphere is caused by the increase in the carbon dioxide emission. But Jeanne thinks that his conclusion is premature. She says: "Before accepting this conclusion you must be sure that other factors that could influence the greenhouse effect are constant".

Name one of the factors that Jeanne means.

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Sample item of TIMSS 2007

How does the average body temperature of people living in hot climates compare to the average body temperature of people living in cold climates?

(Check one box.)

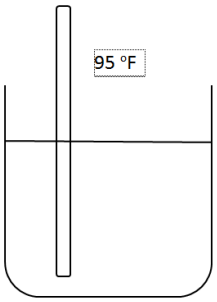
- ☐ Higher in hot climates
- ☐ Lower in hot climates
- ☐ The same in both climates

Explain your answer.

Sample item of UN 2013

Perhatikan gambar pengukuran suhu zat cair dengan thermometer berskala Fahrenheit berikut! Jika suhu zat cair tersebut diukur dengan menggunakan thermometer berskala Celcius, maka besar suhu zat cair tersebut adalah ….

a. 28 °C
b. 35 °C
c. 63 °C
d. 95 °C



The comparison results of three items about temperature above, seen that UN item measures the knowledge of factual knowledge dimension at the level C3 (applying). TIMSS

item measures the knowledge of conceptual dimension at the level C4 (analyzing by comparative/ compare). PISA item measures the ability of C4 (analyzing) and C5 (evaluating in the form of disagreement expression to the opinion of others).

If related with the context of daily life, all questions above already related to daily life. PISA item is the highest in the aspect of contextual, complexity, and reality, while UN item still has lack in the reality aspect for Indonesian context, such as, generally thermometer in Indonesia use Celsius unit, not Fahrenheit. The context of TIMSS item exists between UN and PISA items.

If reviewed from the aspect of scientific literacy, include identify scientific issues, explain or predict phenomena based on science knowledge, and use scientific evidence to make decision and communicate, seen that UN item just measures whether the knowledge of temperature measurement has been mastered by students, while the implementation of that knowledge in the real life has not been measured. PISA item is the best to measure scientific literacy of students by measuring the students ability to use knowledge to explain phenomena and make decisions.

The context of reality life as in the PISA items are very important for the development of higher-order thinking skills as stated by Wheeler & Haertel in Forster (2004) that higher-order thinking skills requires two kinds of contexts. First, the context of problem solving and decision making in daily life and second, the context of high mental process, for example to compare, evaluate, perform inference, and make decisions.

CONCLUSION AND SUGGESTION

Analysis result of the physics items in the UN, TIMSS and PISA based on the aspect of higher-order thinking and scientific literacy shows that the percentage of demands of higher-order thinking process and scientific literacy in the physics items of TIMSS, PISA, and UN are 0.58 ; 0.53; and 0.35 respectively. If related with the context of daily life, the items of TIMSS, PISA, and UN already fulfill it, but items of PISA are the highest in the aspect of contextual, complexity, and reality in the daily life.

Based on the results above, it is recommended nationally (led by the Center of Educational Assessment and the Agency of Educational Quality Assurance (LPMP)) need to be conditioned the development of items that is able to measure higher-order thinking skills (analyze, evaluate, and create) and scientific literacy (identify science issues, explain or predict phenomena based on science knowledge and use scientific evidence to make decision and communicate), with characteristics as described above.

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